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Acremonium camptosporum isolated as an endophyte of *Bursera simaruba* from Yucatan Peninsula, Mexico

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Abstract —An interesting endophytic fungus was isolated from the leaves of *Bursera simaruba,* a tree in the semi-deciduous dry tropical forest at El Eden Ecological Reserve. The cultured strain developed the morphology characteristic of the genus *Acremonium*—tapered phialides and small aseptate conidia clustered in slimy heads. A detailed morphological examination and 28S rDNA sequence analysis identified the Yucatan strain as *Acremonium camptosporum,* an uncommon fungus found previously as a saprobe. The material is described and illustrated as the first record of this species from Mexico.

Key words — anamorphic fungi, *Ascomycota,* clavicipitaceous fungi, *Hypocreales,* taxonomy

Introduction

Acremonium is a complex and diverse genus of *Ascomycota* with widespread global distribution despite its simple morphology (Gams 1971, Glenn et al. 1996, Summerbell et al. 2011, Giraldo et al. 2014). Although *Acremonium*

species are usually isolated as saprobes from plant remains and soil, some taxa are important opportunistic human and plant pathogens (Domsch et al. 2007, Perdomo et al. 2011, Li et al. 2014, Oh et al. 2014). The systematic search for and development of new sources of chemical compounds from *Acremonium* species is also important (Rodríguez Sáiz et al. 2004, Bloemendal et al. 2014).

Bursera simaruba, a frequent co-dominant tree of tropical semi-deciduous forests in the Yucatan Peninsula, is important ecologically because it can grow in poor, clay or sandy, saline soils. Mayan communities use this plant medicinally for its analgesic, antimycotic, and anti-inflammatory properties (Gómez Pompa et al. 2003). *Bursera simaruba* exhibits a notable phenotypic variation associated with an ecotypic differentiation of some ecophysiological characters (Becerra 1999). A search for novel allelochemical compounds from endophytic fungi associated with plant communities at El Eden Ecological Reserve has revealed a distinctive endophytic ascomycete diversity that can serve as a source of new bioactive chemical compounds (González et al. 2007, 2009; Macías Ruvalcaba et al. 2008, 2010). In a survey on the diversity of fungi from El Eden Ecological Reserve, a strain (B101) with morphological characters corresponding to *Acremonium* was isolated from the leaves of *B. simaruba*.

Materials & methods

Fungus isolation and phenotypic study

El Eden Ecological Reserve is located in the State of Quintana Roo in northeastern Yucatan Peninsula (21°13′N 87°11′W). Three *Bursera simaruba* trees from a medium semi-deciduous dry tropical forest ecosystem were randomly sampled; four branches were collected from each tree for transport to the laboratory in labelled Zip-lock® plastic bags and processed within one hour of collection. One asymptomatic entire mature leaf was removed from each branch, submerged in running sterile distilled water for 60 s, and sectioned into 5 mm^2 pieces with sterile scissors. The leaf segments were surface cleaned by sequential washing with sodium hypochlorite solution 0.5% (v/v) (2 min) and ethanol 70% (2 min), rinsed with sterile distilled water, and surface-dried under sterile conditions (Arnold et al. 2001). Four 5 mm^2 leaf segments per Petri dish were plated on malt extract agar culture medium (MEA, Difco™, Becton, Dickinson & Company, Sparks, Maryland, USA) with 4g/L streptomycin sulfate and 5mg/L cyclosporine A added after autoclaving (Dreyfuss 1986). Five Petri dishes were prepared for each leaf and incubated at 25 °C under laboratory conditions and examined daily for a 28 d period. Each fungal colony developed during that period was transferred to MEA in order to obtain axenic isolates that were grouped based on their macro- and micro-morphological characters. Fourteen endophytic fungi, including isolate B101, were recovered from *B. simaruba* leaves. Isolate B101 was grown on cornmeal agar, malt extract agar, potato dextrose agar (CMA, MEA, PDA; Difco™, Becton, Dickinson and Company, Sparks, Maryland, USA), and V8 vegetable juice agar (V8A; V8 juice Campbell®, 160 mL; calcium carbonate Sigma-Aldrich©, 2 g; agar, Difco™, 20 g; distilled water to final volume of 1,000 mL)

(Hanlin & Ulloa 1988). Four Petri dishes were prepared for each culture medium and incubated at 25 ± 1 °C for 28 d. Colony macroscopic attributes (e.g., color, odor, texture, growth rate) for each tested medium were examined at low magnification with a Nikon SMZ745T stereoscopic microscope (Nikon Instruments, Tokyo, Japan) after 7, 14, 21 and 28 d. Color designations follow the Methuen handbook (Kornerup & Wanscher 1978). Microscopic morphological characters (somatic and reproductive features, hyphae, phialides, and conidia) of fungus B101 were studied by slide cultures on PDA or mounted directly in water. Photographs were made using bright field contrast (BC), dark field contrast (DC), and Nomarski differential interference contrast (DIC) with a Nikon DS digital camera using NIS software on a Nikon Eclipse 80i microscope. Images were processed with Adobe Photoshop CS6®. Also, the fungus was studied with a Jeol 5410LV scanning electron microscope according to Goh & Hanlin (1994).

DNA isolation, PCR amplification, sequencing, and phylogenetic analysis

Genomic DNA was extracted for molecular analyses from the endophyte fungus B101 (Glenn et al. 1996). The nuclear 28S large subunit RNA gene (LSU) was amplified with primers LR0R and LR6 and sequenced with primers LROR, LR3, LR3R, LR5, and LR6 (Vilgalys & Hester 1990, Rehner & Samuels 1995). The DNA was sequenced by the USDA-Agricultural Research Service, South Atlantic Area Sequencing Facility (Athens, GA, USA). The LSU sequence from B101 was compared with GenBank sequences using the Geneious v7.1.8 Linnaeus Blast search feature. The compiled LSU dataset was aligned using MUSCLE, also all within Geneious. The alignment was evaluated using MEGA v.6.06 to determine the maximum likelihood nucleotide substitution model having the best fit. Model TN93 (including estimated transition/transversion ratio, proportion of invariable sites, and gamma distribution parameter) was used for PhyML analysis to identify the maximum likelihood cladogram, which was assessed by 200 bootstrap replications. Model GTR with the same estimated parameters was used for MrBayes analysis (10,000,000 chain length; 4 heated chains; 0.2 heated chain temp; 200 subsampling frequency; 0.125 burn-in length). PhyML and MrBayes assessments were conducted within Geneious. Sequences from five species of *Cosmospora/Nectria* were designated as the outgroup.

Fungal specimen

The Mexican endophytic fungus (B101) was deposited in the Colección de Hongos of the Herbario Nacional de México, Universidad Nacional Autónoma de México, Distrito Federal, México (MEXU). In addition, a specimen from the tree from which B101 was isolated was deposited in the Herbarium, University of California, Riverside CA, U.S.A. (G.P. Schultz & R. Palestina # 1092/UCR 110695). The 28S rDNA sequence generated in this study was deposited in GenBank.

Taxonomy

Acremonium camptosporum W. Gams, Cephal.-art. Schimmelp.: 57. 1971. Figs 1–4

Mycelial colonies in vitro growing 30–35 mm diam after 28 d on PDA at 25 °C, flat to slightly elevated in center, funiculose to floccose textured, white (1A1) to yellowish white (1A2), reverse colored with pale yellow ochraceous to

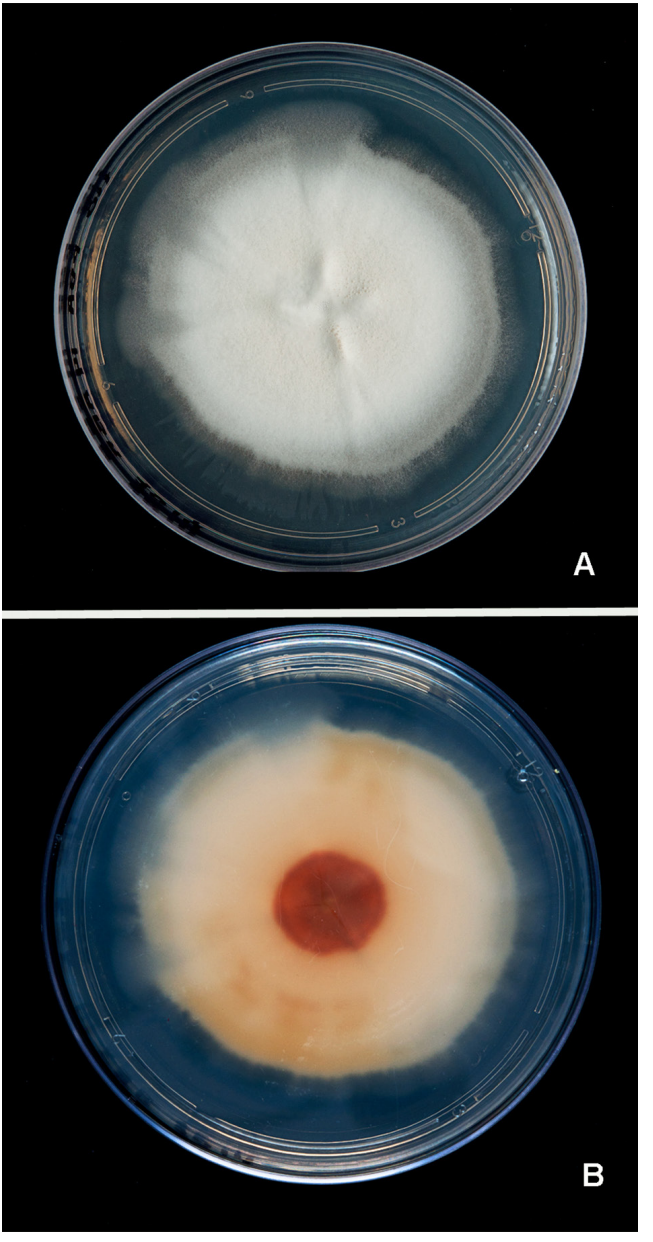


Fig. 1. *Acremonium camptosporum* (MEXU 26354). A. obverse of colony on potato dextrose agar after 28 d at 25 °C; B. reverse of same culture with ochre-brown pigment.

dark yellow ochraceous central area. Cubical or elongated crystals numerous. Odor not pronounced. Somatic hyphae septate, hyaline, smooth- and thin-walled, slightly to highly convoluted, often anastomosed, 0.5–2.5 µm wide, plectonematogenous. Conidiophores often basitonously branched, sporodochia not observed, sporulation abundant. Phialides straight or slightly flexuous, 15–46 µm long, 0.5–1 µm wide at the base, tapering to 0.4–0.5 µm at tip, without a chromophile base, collarette or periclinal thickening at the apex, hyaline, thin- and smooth-walled, slightly constricted at basal septum, orthophialides formed, prostrate phialides present, adelophialides and schizophialides not observed. Conidia aseptate, hyaline, guttulate, smooth- and thin-walled, heteropolar-bilateral, mostly plano-convex or asymmetrically biconvex in front view, 1.5–2.5(–2.8) µm long, 0.8–1.1 µm wide, fusiform in side view, sometimes slightly curved and basally apiculate, aggregated in small slimy globose clusters, catenate conidia not seen. Chlamydospores and sexual morph not observed.

Material examined: **MEXICO. Quintana Roo:** Isla Mujeres Municipality, El Eden Ecological Reserve, 21°13′N 87°11′W, from leaves of *Bursera simaruba* (L.) Sarg. (*Burseraceae*), May 2004, MC González, AL Anaya (MEXU 26354; GenBank JQ811556).

Phylogenetic analysis & discussion

Maximum likelihood (ML) and Bayesian analyses support MEXU 26354 and the *A. camptosporum* isolates within the *Clavicipitaceae* s.l., with particular association with *Elaphocordyceps* and *Metacordyceps* (Fig. 6). Bayesian support was strong for this large clade, but there was no substantial support of this relationship from the ML analysis. In general the Bayesian analysis was more supportive of the major clades than was ML. The relationship between MEXU 26354 and the other *A. camptosporum* isolates was very well supported (Bayesian posterior probability = 1; ML bootstrap = 100%). The LSU sequence of MEXU 26354 was 99.5–99.7% identical to the four *A. camptosporum* accessions.

According to Summerbell et al. (2011), *Acremonium* can be morphologically characterized by its conidiophores that are mainly unbranched or poorly basitonously branched and subglobose, obovate– ellipsoidal conidia, with adelophialides usually absent. However, they conclude that because of the relatively common plasticity of form in *Acremonium* and acremonioid species, the distinctive LSU sequences for delineating the species phylogenetically, precise morphological observation, and correct interpretation of the morphological descriptions are all necessary.

Gams (1971) described the type specimen of *Acremonium camptosporum* from Kiel-Kitzeberg, Germany; his description and drawings depict structures that are similar with those produced by the Mexican collection MEXU 26354.

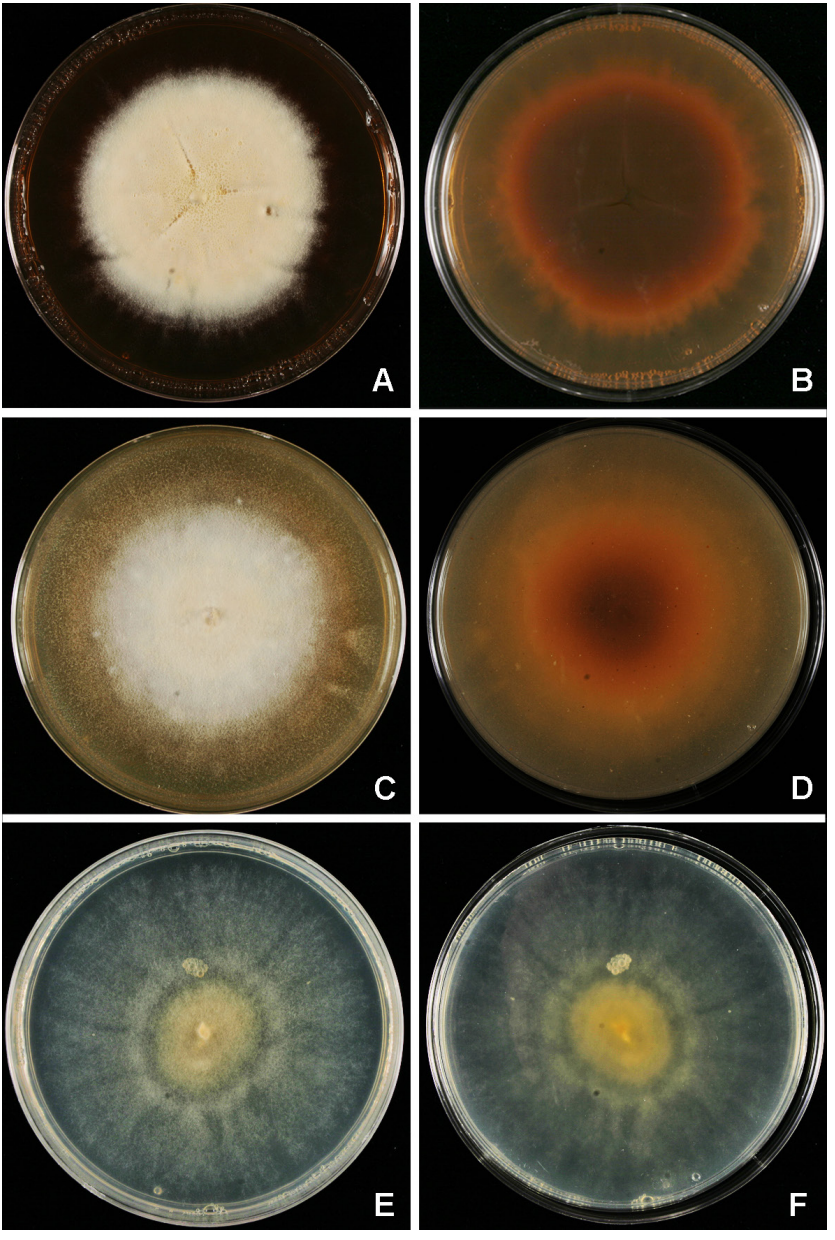


Fig. 2. *Acremonium camptosporum* (MEXU 26354). A, C, E: obverse of colonies on malt extract agar, V-8 juice agar, and corn meal agar after 28 d at 25 °C; B, D, F. reverse of same cultures.

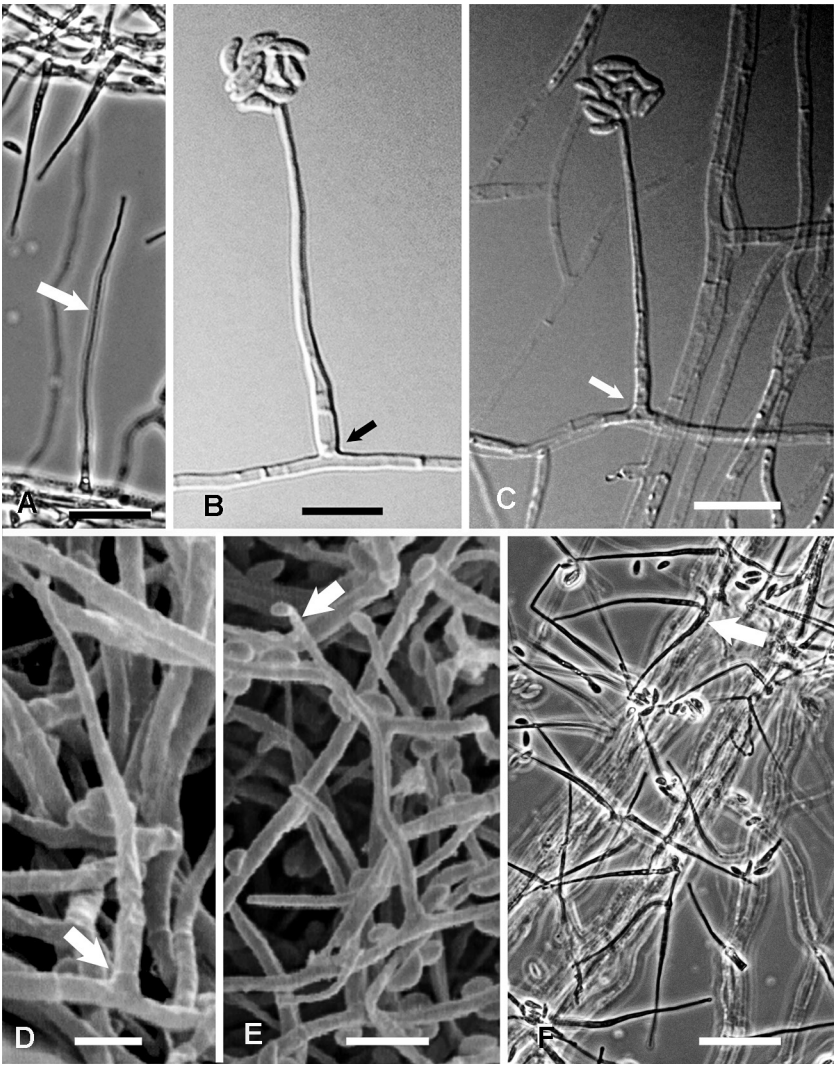


Fig. 3. *Acremonium camptosporum* (MEXU 26354). A. phialides – arrow indicates one longer and narrower; B. phialide slightly constricted at basal septum (arrow) and conidia clustered in slimy head; C, D. orthophialide with basal septum (arrow); E. flexuous phialide with phialospore attached at tip (arrow); F. plectonematogenous sporulation, phialides unbranched and branched (arrow). Scale bars: A = 10 µm; B–E = 5 µm; F = 20 µm.

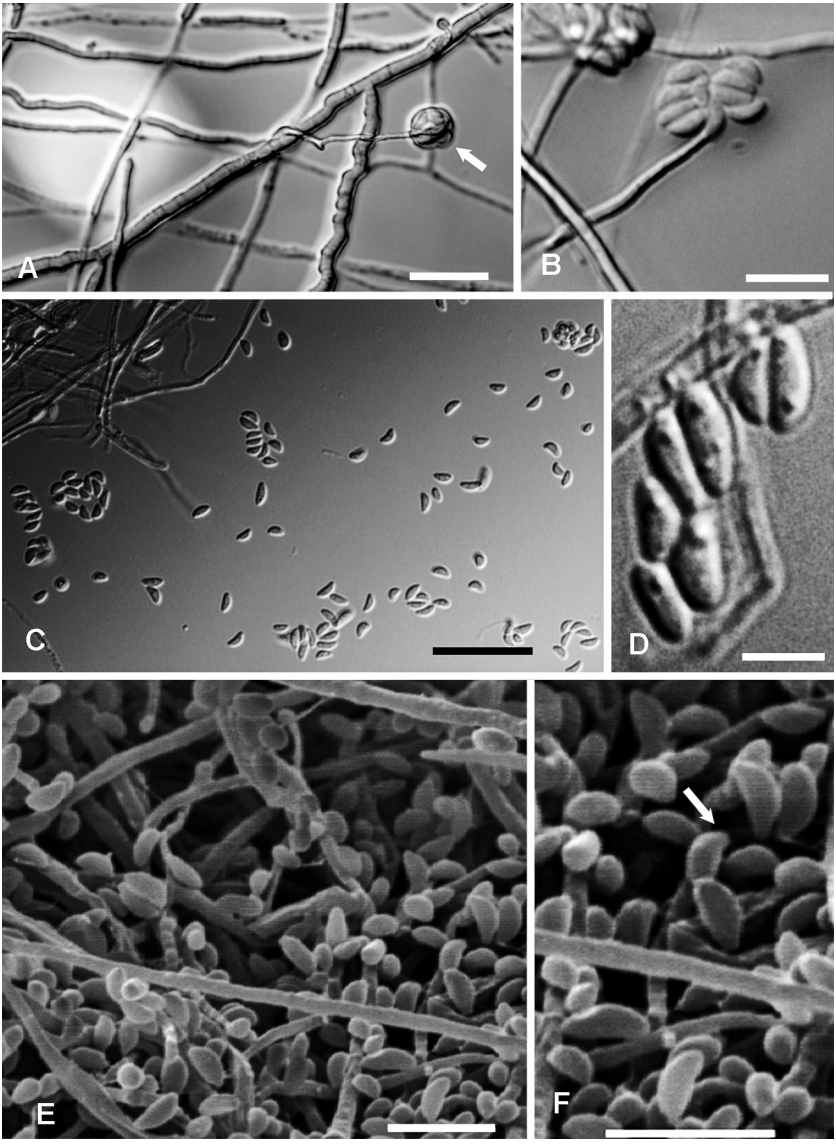


Fig. 4. *Acremonium camptosporum* (MEXU 26354). A. tiny prostrate hypha with subterminal phialide and conidia clustered in subglobose slimy head (arrow); B. phialidic development of curved phialoconidia; C. small hyaline curved conidia; D. guttulate conidia; E. aseptate conidia; F. slightly curved and basically apiculate (arrow) and plano-convex conidiospores. Scale bars: A, C = 10 µm; B, E, F = 5 µm; D = 2 µm.

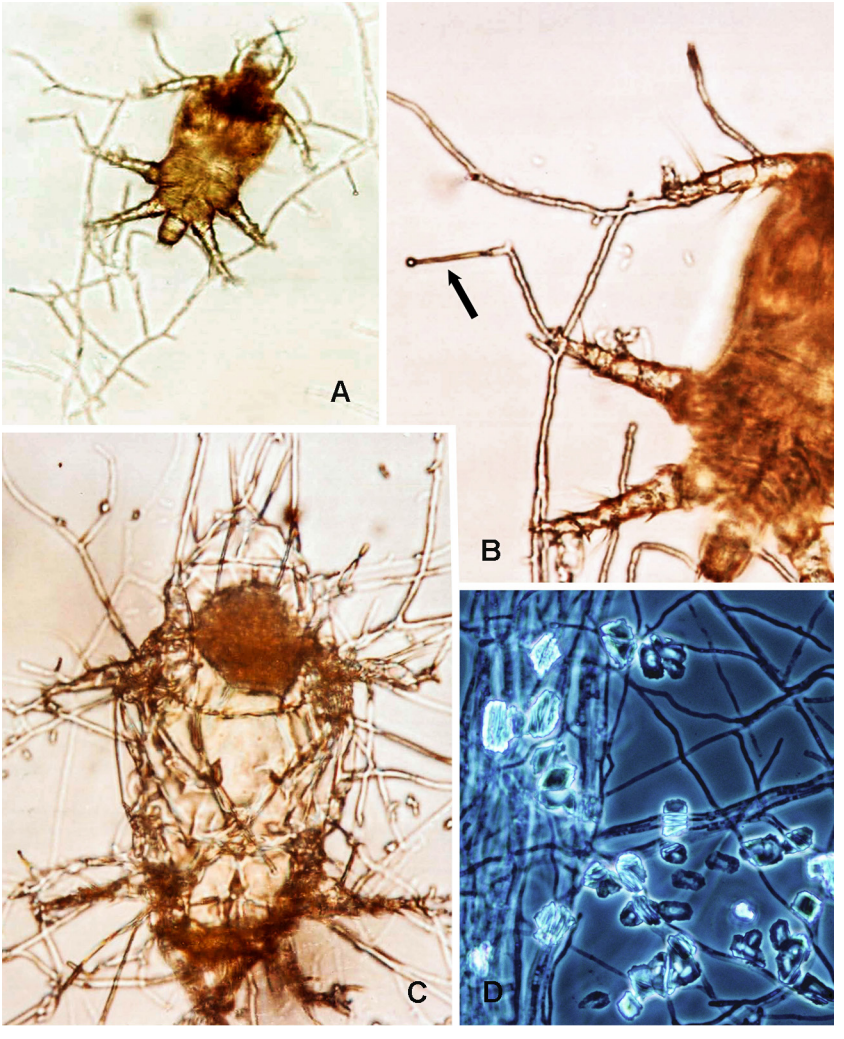


Fig. 5. *Acremonium camptosporum.* A. dead mite attached to internal lateral wall of Petri dish by *A. camptosporum* hyphae from edge of 6 wk old pure culture; B. detail of mite legs with hyphae of *A camptosporum*; note a phialide with globose mass of conidia (arrow); C. dead mite in advanced state of degradation by *A. camptosporum*;. D. cubical and irregular crystals.

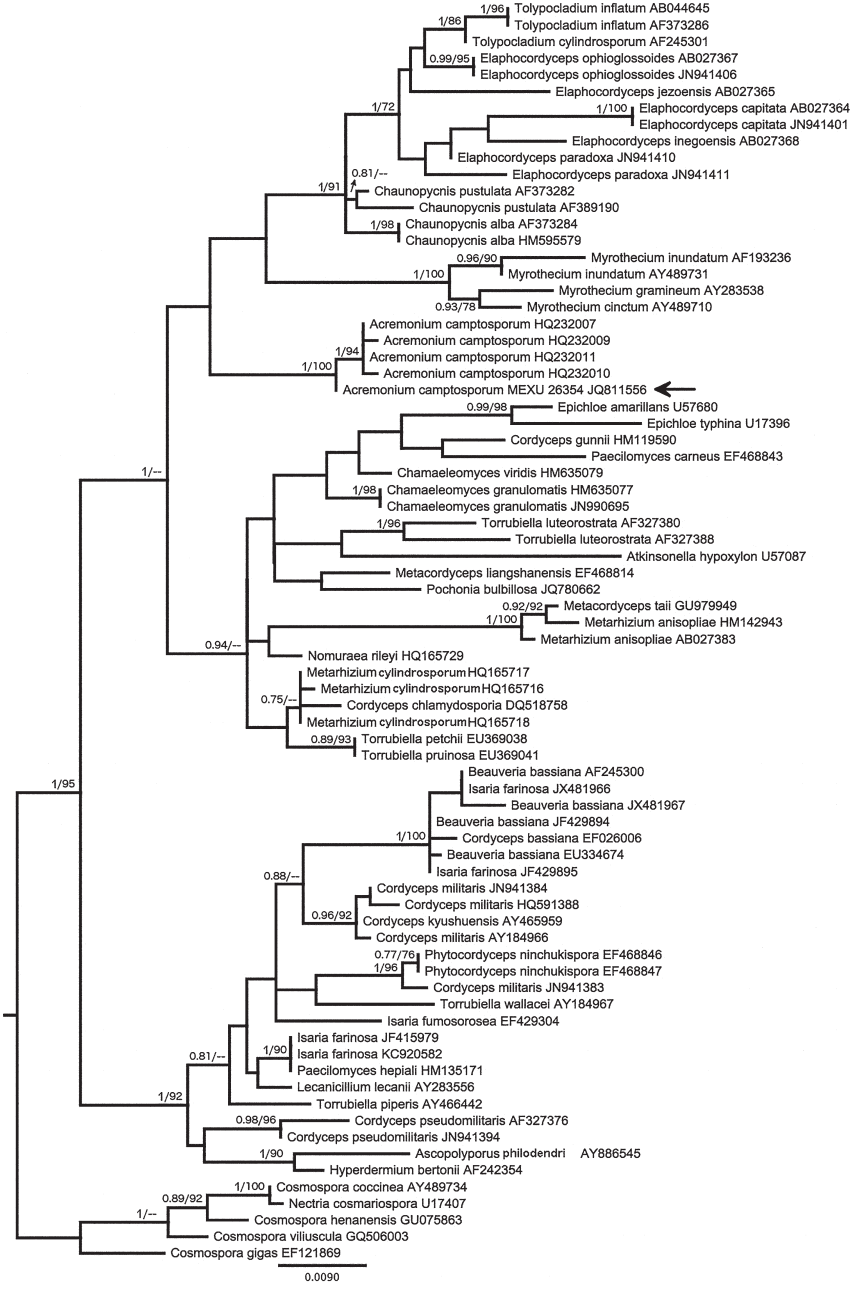
As described by as Gams (1971), *A. camptosporum* is characterized by slow-growing white colonies with a yellow ochre reverse, the presence of orthotropic phialides, and small curved conidia arranged in slimy heads. The Mexican specimen has the same micro-morphological characteristics and agrees with

the *A. camptosporum* description, particularly with the variable form of its conidia (slightly curved and basally apiculate, heteropolar-bilateral, plano-convex or asymmetrically biconvex) and the presence of characteristic crystals (Fig. 5D). However, the Mexican material has conidia that are minutely guttulate (sometimes with one or two conspicuous guttules) and slightly smaller, with maximum measurement values corresponding to the minimum values mentioned in Gams's description (2.8–3.8 µm long × 1.1–1.8 µm wide). Gams (1971) also noted the presence of sporodochial conidiomata in older cultures—not observed in our cultures, although delimited higher sporulation zones were noted in central area of colonies. Although the conidia of MEXU 26354 are smaller than those of the type description, based on our phenotypic and phylogenetic analyses, we conclude that our material represents *A. camptosporum*.

Gams (1971) mentioned that *A. camptosporum* shares some morphological characters with *Xenoacremonium recifei* [≡ *Acremonium recifei* = *Cephalosporium recifei* = *Hyalopus furcatus* = *Hyalopus recifei*], a tropical opportunistic pathogen of humans characterized by aseptate, hyaline, ellipsoidal to fusiform or reniform, slightly curved conidia, but *X. recifei* can be distinguished by its shorter conidia without periclinal thickening, slower colony development, and intensive pigmentation of the colony reverse.

Our results support a close phylogenetic relationship between *Acremonium camptosporum* and the clade encompassing *Ophiocordycipitaceae* and *Clavicipitaceae* s. str. (Sung et al. 2007) (Fig. 6). Interestingly, our study also nests the *A. camptosporum* clade with the *Elaphocordyceps* clade. Data analysis suggests that *A. camptosporum* is basal to *Elaphocordyceps* and other fungi with asexual morphology in the *Ophiocordycipitaceae*. The *Elaphocordyceps* clade contains the asexual genera *Tolypocladium* and *Chaunopycnis*. *Tolypocladium* species typically produce smooth globose or cylindrical conidia on inflated-base phialides with slightly tapering apex. They are parasites of the ectomycorrhizal truffle-like genus *Elaphomyces*, entomopathogens of cicada nymphs buried in soil, and scarab beetle larvae embedded in decaying wood and are also isolated from soil (Gams 1971, Sung et al. 2007). *Chaunopycnis* species produce minutely roughened globose or obovate conidia on cylindrical or inflated-base phialides slightly tapering in the distal part, formed in conidiomata isolated

Fig. 6. LSU sequence cladogram (PhyML) showing the relationship of *Acremonium camptosporum* to other taxa within the *Clavicipitaceae* sensu lato. Numbers above branches indicate the Bayesian posterior probability support (>0.75) followed by the bootstrap support (>75%) from 200 maximum likelihood replicates.


1/96
Tolypocladium inflatum AB044645
1/86
Tolypocladium inflatum AF373286
Tolypocladium cylindrosporum AF245301
0.99/95
Elaphocordyceps ophioglossoides AB027367
Elaphocordyceps ophioglossoides JN941406
Elaphocordyceps jezoensis AB027365
1/72
1/100
Elaphocordyceps capitata AB027364
Elaphocordyceps capitata JN941401
Elaphocordyceps inegoensis AB027368
Elaphocordyceps paradoxa JN941410
0.81/--
Elaphocordyceps paradoxa JN941411
1/91
Chaunopycnis pustulata AF373282
Chaunopycnis pustulata AF389190
1/98
Chaunopycnis alba AF373284
Chaunopycnis alba HM595579
0.96/90
Myrothecium inundatum AF193236
1/100
Myrothecium inundatum AY489731
Myrothecium gramineum AY283538
0.93/78
Myrothecium cinctum AY489710
Acremonium camptosporum HQ232007
Acremonium camptosporum HQ232009
1/94
Acremonium camptosporum HQ232011
1/100
Acremonium camptosporum HQ232010
Acremonium camptosporum MEXU 26354 JQ811556
0.99/98
Epichloe amarillans U57680
Epichloe typhina U17396
Cordyceps gunnii HM119590
Paecilomyces carneus EF468843
1/--
Chamaeleomyces viridis HM635079
1/98
Chamaeleomyces granulomatis HM635077
Chamaeleomyces granulomatis JN990695
1/96
Torrubiella luteorostrata AF327380
Torrubiella luteorostrata AF327388
Atkinsonella hypoxylon U57087
Metacordyceps liangshanensis EF468814
Pochonia bulbillosa JQ780662
0.92/92
Metacordyceps taii GU979949
1/100
Metarhizium anisopliae HM142943
Metarhizium anisopliae AB027383
0.94/--
Nomuraea rileyi HQ165729
Metarhizium cylindrosporum HQ165717
Metarhizium cylindrosporum HQ165716
0.75/--
Cordyceps chlamydosporia DQ518758
Metarhizium cylindrosporum HQ165718
0.89/93
Torrubiella petchii EU369038
Torrubiella pruinosa EU369041
1/95
Beauveria bassiana AF245300
Isaria farinosa JX481966
Beauveria bassiana JX481967
Beauveria bassiana JF429894
1/100
Cordyceps bassiana EF026006
Beauveria bassiana EU334674
Isaria farinosa JF429895
0.88/--
Cordyceps militaris JN941384
Cordyceps militaris HQ591388
0.96/92
Cordyceps kyushuensis AY465959
Cordyceps militaris AY184966
0.77/76
Phytocordyceps ninchukispora EF468846
1/96
Phytocordyceps ninchukispora EF468847
Cordyceps militaris JN941383
Torrubiella wallacei AY184967
Isaria fumosorosea EF429304
Isaria farinosa JF415979
1/90
Isaria farinosa KC920582
0.81/--
Paecilomyces hepiali HM135171
Lecanicillium lecanii AY283556
1/92
Torrubiella piperis AY466442
0.98/96
Cordyceps pseudomilitaris AF327376
Cordyceps pseudomilitaris JN941394
1/90
Ascopolyporus philodendri AY886545
Hyperdermium bertonii AF242354
1/100
Cosmospora coccinea AY489734
0.89/92
Nectria cosmariospora U17407
1/--
Cosmospora henanensis GU075863
Cosmospora viliuscula GQ506003
Cosmospora gigas EF121869
0.0090

from soil, plant litter, crustose lichen thalli of *Caloplaca regalis*, and living leaves of *Kalmia latifolia* (Gams 1980, Möller & Gams 1993, Bills et al. 2002). The Mexican *A. camptosporum* strain (MEXU 26354) differs morphologically and ecologically from those taxa. More robust statistical analyses still needed for a higher-level phylogeny of *A. camptosporum*.

The endophyte strain of *A. camptosporum* (MEXU 26354) produces six secondary metabolites of three different heterodimeric polyketide groups, one of which is acremoxanthone E, a new compound that shows biological activity against selected phytopathogens and human tumor cell lines (Meléndez-González et al. 2015).

Acremonium camptosporum is a rarely isolated fungus, previously reported only from air in Germany (Gams 1971); soil in Czech Republic (Řepová 1989), Ivory Coast (Persiani et al. 1998), and Brazil (Prade 2007); and anthropogenic substrates in Czech Republic (Váňová & Bečvář 1998) and Poland (Blyskal 2009, 2015). Additional nucLSU sequences from leaf litter of *Acacia karroo* soil in South Africa (CBS 757.69, CBS 677.74), from insects in Cuba (CBS 835.91), and from soil nematodes in Germany (CBS 890.85) give a broad view of *A. camptosporum* distribution and ecology. This is both the first record of *A. camptosporum* from Mexico and the first record of the species as a leaf endophyte.

Melanins function in protecting fungi from adverse environmental factors (Gómez & Nosanchuk 2003). Some *Sarocladium* species have an ochre-brown or dark grey-brown colony reverse due to melanin synthesis (Summerbell et al. 2011). The Mexican *A. camptosporum* strain produces yellow ochre to ochre-brown pigments on the reverse of colonies cultured. The highest color intensity was expressed on MEA, whereas it was colorless on CMA (Fig. 2B, F).

In a recent study on biodeterioration of cochineal dyed antique woolen textiles, *A. camptosporum* caused significant degradation of wool fibers due to its ability to utilize keratinous materials (Blyskal 2009, 2015). The keratin-associated proteins and high glycine-tyrosine proteins of wool fibers are a good nutritional resource for small arthropods (e.g., mites), and keratins for fungi and other microorganisms. Interestingly, we observed here the apparent degradation of a dead mite by the *A. camptosporum* MEXU 26354 endophytic strain (Fig. 5A–C).

The smaller somatic and reproductive structures of the *A. camptosporum* endophytic strain from *Bursera simaruba* leaves of Yucatan Peninsula, along with its apparent keratinophilic ability, suggest a possible adaptation to its niche. More studies are necessary to clarify the ecology of this fungus.

Acknowledgments

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Literature cited

Arnold AE, Maynard Z, Gilbert GS. 2001. Fungal endophytes in dicotyledonous neotropical trees: patterns of abundance and diversity. Mycological Research 105: 1502–1507. http://dx.doi.org/10.1017/S0953756201004956

Becerra JX, Venable DL. 1999. Nuclear ribosomal DNA phylogeny and its implications for evolutionary trends in Mexican *Bursera* (*Burseraceae*). American Journal of Botany 86: 1047–1057. http://dx.doi.org/10.2307/2656622

Bills GF, Polishook JD, Goetz MA, Sullivan RF, White JF. 2002. *Chaunopycnis pustulata* sp. nov., a new clavicipitalean anamorph producing metabolites that modulate potassium ion channels. Mycological Progress 1: 3–17. http://dx.doi.org/10.1007/s11557-006-0001-3

Bloemendal S, Löper D, Terfehr D, Kopke K, Kluge J, Teichert I, Kück U. 2014. Tools for advanced and targeted genetic manipulation of β-lactam antibiotic producer *Acremonium chrysogenum.* Journal of Biotechnology 169: 51–62. http://dx.doi.org/10.1016/j.jbiotec.2013.10.036

Blyskal B. 2009. Fungi utilizing keratinous substrates. International biodeterioration & biodegradation 63: 631–653. http://dx.doi.org/10.1016/j.ibiod.2009.02.006

Blyskal B. 2015. Fungal deterioration of a woolen textile dyed with cochineal. Journal of Cultural Heritage 16: 31–39. http://dx.doi.org/10.1016/j.culher.2014.01.008

Domsch KH, Gams W, Anderson TH. 2007. Compendium of soil fungi. Eching, Germany: IHW-Verlag.

Dreyfuss MM. 1986. Neue Erkenntnisse aus einem pharmakologischen Pilz-Screening. Sydowia 39: 22–36.

Gams W. 1971. *Cephalosporium*-artige Schimmelpilze (*Hyphomycetes*). Stuttgart, Germany: Gustav Fisher Verlag.

Gams W. 1980. *Chaunopycnis alba*, gen. et sp. nov., a soil fungus intermediate between *Moniliales* and *Sphaeropsidales*. Persoonia 11: 75–79.

Giraldo A, Gené J, Cano J, de Hoog S, Decock C, Guarro J. 2014. *Acremonium* with catenate elongate conidia: phylogeny of *Acremonium fusidioides* and related species. Mycologia 106: 328–338. http://dx.doi.org/10.3852/13-158

Glenn A, Bacon CW, Price R, Hanlin RT. 1996. Molecular phylogeny of *Acremonium* and its taxonomic implications. Mycologia 88: 369–383. http://dx.doi.org/10.2307/3760878

Goh TK, Hanlin RT 1994 Ascomal development in *Melanospora zamiae*. Mycologia 86: 357–370. http://dx.doi.org/10.2307/3760566

Gómez BL, Nosanchuk JD. 2003. Melanin and fungi. Current Opinion in Infectious Diseases 16: 91–96. http://dx.doi.org/10.1097/00001432-200304000-00005

Gómez Pompa A, Allen MF, Fedick SL, Jiménez Osornio JJ. 2003. The lowland Maya area: Three millennia at the human-wildland interface. Food Products Press, New York.

González MC, Anaya A, Glenn A, Saucedo-García A, Macías-Rubalcava ML, Hanlin RT. 2007. A new endophytic ascomycete from El Eden Ecological Reserve, Quintana Roo, Mexico. Mycotaxon 101: 251–260.

González MC, Anaya AL, Glenn AE, Macías-Rubalcava ML, Hernández-Bautista BE, Hanlin RT. 2009. *Muscodor yucatanensis*, a new endophytic ascomycete from Mexican chakah, *Bursera simaruba*. Mycotaxon 110: 363–372. http://dx.doi.org/10.5248/110.363

Hanlin RT, Ulloa M. 1988. Atlas of introductory mycology. Hunter Textbooks Inc. Winston-Salem, North Carolina USA.

Kornerup A, Wanscher JH. 1978. Methuen handbook of colour, 3rd edition. Eyre Methuen, London.

Li BH, Wang CC, Dong XL, Zhang ZF, Wang CX. 2014. *Acremonium* brown spot, a new disease caused by *Acremonium sclerotigenum* on bagged apple fruit in China. Plant Disease 98: 1012. http://dx.doi.org/10.1094/PDIS-02-14-0113-PDN

Macías-Rubalcava ML, Hernández Bautista BE, Jiménez Estrada M, González MC, Glenn AE, Hanlin RT, Hernández Ortega S, Saucedo García A, Muria González JM, Anaya AL 2008. Naphthoquinone spiroketal with allelochemical activity from the newly discovered endophytic fungus *Edenia gomezpompae*. Phytochemistry 69: 1185–1196. http://dx.doi.org/10.1016/j.phytochem.2007.12.006

Macías-Rubalcava ML, Hernández-Bautista BE, Oropeza F, Duarte G, González MC, Glenn AE, Hanlin RT, Anaya AL. 2010. Allelochemical effects of volatile compounds and organic extracts from *Muscodor yucatanensis*, a tropical endophytic fungus from *Bursera simaruba*. Journal of Chemical Ecology 36: 1122–1131. http://dx.doi.org/10.1007/s10886-010-9848-5

Meléndez-González C, Murià-González MJ, Anaya AL, Hernández-Bautista BE, Hernández-Ortega S, González MC, Glenn AE, Hanlin RT, Macías-Rubalcava ML. 2015. Acremoxanthone E, a novel member of heterodimeric polyketides with a bicyclo[3.2.2]nonene ring, produced by *Acremonium camptosporum* W. Gams (*Clavicipitaceae*) endophytic fungus. Chemistry & Biodiversity 12: 133–147. http://dx.doi.org/10.1002/cbdv.201300370

Möller C, Gams W. 1993. Two new hyphomycetes isolated from Antarctic lichens. Mycotaxon 48: 441–450.

Oh SY, Nam KW, Yoon DH. 2014. Identification of *Acremonium acutatum* and *Trichothecium roseum* isolated from grape with white stain symptom in Korea. Mycobiology 42: 269–273. http://dx.doi.org/10.5941/MYCO.2014.42.3.269

Perdomo H, Sutton DA, García D, Fothergill AW, Cano J, Gené J, Summerbell RC, Rinaldi MG, Guarro J. 2011. Spectrum of clinically relevant *Acremonium* species in the United States. Journal of Clinical Microbiology 49: 243–256. http://dx.doi.org/10.1128/JCM.00793-10

Persiani AM, Maggi O, Casado MA, Pineda FD. 1998. Diversity and variability in soil fungi from a disturbed tropical rain forest. Mycologia 90: 206–214. http://dx.doi.org/10.2307/3761296

Prade CA, Matsumura AT, Ott AP, Porto ML. 2007. Diversidad de fungos do solo em sistemas agroflorestais de *Citrus* com diferentes tipos de manejo no Município de Roca Sales, Rio Grande do Sul, Brasil. Biociéncias 15: 73–81.

Rehner SA, Samuels GJ. 1995. Molecular systematics of the *Hypocreales*: a teleomorph gene phylogeny and the status of their anamorphs. Canadian Journal of Botany 73(Suppl. 1): S816–S823.

Řepová A. 1989. Soil micromycetes of Czechoslovakia – a list of isolated species with bibliography I. Česka Mykologie 43: 169–175.

Rodríguez Sáiz M, Lembo M, Bertetti L, Muraca R, Velasco J, Malcangi A, de la Fuente JL, Barredo JL. 2004. Strain improvement for cephalosporin production by *Acremonium chrysogenum* using geneticin as a suitable transformation marker. FEMS Microbiology Letters 235: 43–49. http://dx.doi.org/10.1111/j.1574-6968.2004.tb09565.x

Summerbell RC, Gueidan C, Schroers HJ, de Hoog GS, Starink M, Arocha Rosete Y, Guarro J, Scott JA. 2011. *Acremonium* phylogenetic overview and revision of *Gliomastix*, *Trichothecium* and *Sarocladium*. Studies in Mycology 68: 139–162. http://dx.doi.org/10.3114/sim.2011.68.06

Sung GH, Hywel-Jones NL, Sung JM, Luangsa-ard JJ, Shrestha B, Spatafora JW. 2007. Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. Studies in Mycology 57: 5–59. http://dx.doi.org/10.3114/sim.2007.57.01

Váňová M, Bečvář K. 1998. Ecology of communities of saprotrophic micromycetes and their succession in anthropogenic substrates. Final report of project FRVŠ 10-981405, Prague.

Vilgalys R, Hester M. 1990. Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several *Cryptococcus* species. Journal of Bacteriology 172: 4238–4246. http://dx.doi.org/0021-9193/90/084238-09